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SPACE EXPLORATION

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SPACE EXPLORATION

FOUR YEARS after launching of the first Russian sputnik, Oct. 4, 1957, the rocket program of the United States finally is hitting its stride. Ever-larger payloads are being projected into outer space in fairly rapid succession. Speed-up of the program in the past few months has been due not only to the challenge of Soviet successes in manned flight but also to President Kennedy's dedication of the nation to an all-out effort to launch a manned expedition to the moon before the end of the decade.

In a special message to Congress on May 25, the President said he believed "we should go to the moon" even though "the lead obtained by the Soviets with their large rocket engines" would not be easy to overcome. James E. Webb, head of the National Aeronautics and Space Administration, has said that while the Russians at present surpass the United States in rocket power, neither country yet has "rockets capable of sending a man to the moon and returning him safely." In consequence, this country has a nearly even start.[1]

Webb explained that the time required by the United States to overtake the Russian lead in rocket thrust will depend on what the Soviet Union is doing. The U.S.S.R., whose rocket program is kept under tight wraps, is thought now to have a two-to-one advantage in rocket power. However, the American Saturn booster, which had its first and highly successful test firing at Cape Canaveral on Oct. 27, is expected to develop more power than anything yet revealed by the Russians. Vice President Lyndon B. Johnson said, Oct. 2, that America's "future as a free nation is at stake" and that "we dare not lose" the race with the Soviet Union.

Doubts about this country's ability to beat the Russians to the moon have nevertheless had frequent expression. James A. Van Allen, a leading space scientist, asserted at a meeting of the American Rocket Society on Oct. 10 that

[1] Interview with James E. Webb, *Washington Daily News*, Oct. 2, 1961, p. 27.

American ambitions in the field of space exploration had greatly outrun basic scientific competence. Rep. Perkins Bass (R N.H.) had said earlier (July 27) that "If we try to match the Russians . . . on a crash basis, we will not be sure of catching up." Bass, a member of the House Committee on Science and Astronautics, thinks the United States cannot put a man on the moon before 1967 at the earliest and that "The chances are that the Russians will still beat us to the moon before that date."

Reasons for Undertaking the Lunar Expedition

Robert C. Seamans, Jr., associate administrator of NASA, said in California on Aug. 29 that the President's decision to marshal the resources required for leadership in space had four basic objectives: (1) To forward "the quest for scientific knowledge"; (2) to acquire new knowledge to speed the development of satellite systems for communications, weather forecasting and navigation; (3) to "avoid the risk of delay in the competitive situation with the Communists"; and (4) to reap the benefits of "the technological advances and stimulus to our economy that will emerge from the space effort." [2]

President Kennedy had said in his message to Congress on May 25 that "We go into space because whatever mankind must undertake, free men must fully share." He voiced concern lest the United States, by failing to make the utmost effort, lose out in still unexplored areas. As for technological and economic gains, administration officials have pointed out that requirements of space exploration have already led to development of new materials, alloys, metals, compounds and fabrics. From work in extreme temperatures have come new durable, unbreakable plastics and new types of glass that have a wide variety of uses. Moreover, the satellite experimentation so far undertaken has pointed the way to improved communication and weather forecasting services.[3]

The scientific community has debated the need of sending a man, as opposed to an instrument package, to the moon. Vannevar Bush, head of the wartime Office of Scientific Research and Development, said on May 24 that "There is nothing a man can do in space that can't be done better and more cheaply by instruments." Seamans as-

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[2] Speech at Los Angeles and news conference in Pasadena.

[3] See "Space Communications," *E.R.R.*, 1961 Vol. II, pp. 698-700.

serted in his Aug. 29 speech, however, that manned flights were necessary because "integration of a human pilot into an onboard spacecraft system greatly improves reliability."

Instrumented satellites cannot make repairs, nor can they make in-flight tests.[4] The most advanced instruments can perform only as they are programmed to perform; instruments lack the flexibility of human reasoning. On-the-spot corrections cannot be made by instruments, and man outstrips any computer in his ability to make emergency decisions. Finally, there is recognition that manned flight in space has a much greater psychological impact on people everywhere than do instrumented shots. The United States, as well as the Soviet Union, is now aware of the importance of that impact.

NASA Administrator Webb has emphasized that the practical value of putting a man on the moon is that it will stimulate the United States to push its technological development at the fastest rate possible. Although the moon is believed to have no military value, there can now be no doubt of the military value of developing more powerful rocket boosters. The hardware and techniques used to send up a scientific capsule can be used also to orbit an early warning satellite.[5] Rep. Emilio Q. Daddario (D Conn.), a member of the House Committee on Science and Astronautics, has pointed out that the space effort would help to spur development of an anti-missile missile.[6]

GREAT COST OF SENDING MAN TO MOON AND BACK

President Kennedy has estimated that to send a man to the moon and bring him safely back to earth will add about $7 billion to $9 billion to the country's expenditures for space exploration in the course of the next five years. Much larger expenditures thereafter, to build the enormous rocket boosters required and to overcome various likely obstacles, are expected to lift the final aggregate outlay for the moon project to the neighborhood of $40 billion, almost 20 times the cost of the Manhattan A-bomb project of World War II.

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[4] Eight out of 40 NASA rocket airplane missions to date would have failed without a pilot in the cockpit to correct malfunctions of equipment, instruments, or power plant. An X-15 pilot was able to guide the plane to the fringes of outer space, at speeds above 3,000 miles an hour, when instrumentation on the plane failed. On Oct. 11, an X-15 flew at an altitude of more than 40 miles at 3,477 miles an hour. The plane attained a speed of 3,920 miles an hour, at a lower altitude, on Oct. 17.

[5] Copyrighted interview with *U.S. News & World Report*, July 3, 1961, p. 59.

[6] Emilio Q. Daddario, "A Job for the Military, Too," *New York Times*, Oct. 8, 1961, Special space section, p. 18.

Unforeseen contingencies may send the costs even higher. James R. Killian, Jr., of the Massachusetts Institute of Technology, who was President Eisenhower's Special Assistant for Science and Technology, said at a meeting of Columbia University's American Assembly, Oct. 19, that achievement of the country's goals in outer space and its commitment to beat the Russians to the moon might "involve expenditures far greater than the figures which have been projected." [7]

NASA's budget of $1.67 billion for fiscal 1962 is dominated by the $1.2 billion scheduled for research and development of propulsion systems, propellants, power supplies, structures and materials, guidance and control, instrumentation telemetry, aerodynamics, launch vehicles, and the satellite program. Major items for research and development include $160 million for Project Apollo, an attempt to develop a three-man space craft to circle the moon as a prelude to manned moon landings; almost $50 million for design and development of the huge Nova rocket, intended to propel future space vehicles to the moon; $59 million to develop test and launch facilities for the Nova rocket; and $57 million to develop the F-1 liquid hydrogen engine to propel the Nova rocket.

The NASA program for fiscal 1962 is approximately twice as costly as was the 1961 program, and the fiscal 1963 program will be still bigger.[8] Vice President Johnson, chairman of the National Aeronautics and Space Council, made public on Oct. 2 an estimate that the American space effort in its entirety might ultimately consume 1 per cent of the country's gross national product. Space exploration is becoming an industry in itself. More than 5,000 manufacturers' and research organizations are now engaged in missile or other space activities. The communications, electronics, chemical and metals industries are all increasingly involved. NASA's announcement, Sept. 19, that Houston, Texas, had been chosen as the site for a $60 million manned space flight laboratory, which is to be the command post for the moon project, is expected to make that region a leading scientific and technological center.[9]

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[7] The Assembly, attended by 65 prominent Americans, warned against development of an obsession to put a man on the moon.

[8] NASA's budget has risen from $339 million in fiscal 1958 to $964 million in fiscal 1960, and $1.67 billion in fiscal 1962.

[9] New Orleans had already been designated as the assembly point for Project Apollo's booster rockets, and Cape Canaveral as the eventual launching site.

REORGANIZATION OF THE NATIONAL SPACE AGENCY

A special task force headed by Jerome B. Wiesner of the Massachusetts Institute of Technology reported to President-elect Kennedy on Jan. 11 that there was "an urgent need to establish more effective management and coordination of the United States space effort." The task force called for "a vigorous, imaginative and technically competent top management for NASA." President Kennedy appointed James E. Webb, an Under Secretary of State in the Truman administration, to head the agency. Up to the time of Webb's appointment, NASA had been caught in a running fight with the Air Force, which hoped to recapture space exploration from civilian hands.[10]

In recent months certain steps have been taken to give NASA the decisive type of management needed to run the most complex and costly undertaking in history. Reorganization within its own ranks has streamlined the agency's chain of command.[11] Although the reorganization will place new emphasis on manned space flight, space sciences, and practical applications of space technology, the vague dividing line between projects under NASA's jurisdiction and those under Air Force jurisdiction is a remaining impediment. Science administrators look on this problem as the next major organizational task, because the closest possible coordination between civilian and military efforts will be required to achieve mastery of space.

Initial Steps in Exploration of Space

INTERPLANETARY TRAVEL is as old a dream as flight itself. As early as 100 A.D. Lucian of Samosata wrote the *True History* of a seagoing vessel which was blown to the moon by a storm. According to tradition, a Chinese named Wan Hoo rode a rocket vehicle about 1500 A.D. with unknown results. Wan Hoo fixed two large kites to a framework, attached 47 gunpowder rockets, and placed a saddle in the center. After he had been seated in the saddle, 47 torch bearers lit the rockets and Wan Hoo disappeared.

[10] John Lear, "The Moon and Four Thousand Billion Pence," *Saturday Review*, Aug. 5, 1961, p. 30.

[11] NASA came into existence Oct. 1, 1958, two months after approval of the National Aeronautics and Space Act of (July 29) 1958. See "National Space Policy," *E.R.R.*, 1959 Vol. II, pp. 918-920.

Jules Verne in a science fiction novel which appeared in 1865, *De la Terre a la Lune,* wrote of a moonship, prophetically launched from Florida, that was steered in space by rockets. Verne described problems of weightlessness in great detail. Konstantin E. Ziolkovsky, a Russian school teacher, wrote a paper in 1898 suggesting the possibility of building a rocket that could escape the pull of the earth's gravity through use of liquid fuel mixed with liquid oxygen as a propellant. Ziolkovsky, regarded as the father of Russian space exploration, wrote that such rockets could be used as observation stations and that, once the moon had been reached, man would be able to put a space vehicle into almost any orbit.

Early Rocket Research and Unmanned Rockets

Robert H. Goddard, American physicist, conducted extensive research on rockets between 1914 and World War II. Goddard's principal object was exploration of the atmosphere. He conducted the first successful test of a liquid-fuel rocket in 1926 and calculated the size of a rocket engine that would be capable of going to the moon. However, the efforts of Goddard and of other American rocket enthusiasts went largely unnoticed. Meanwhile, Hermann Oberth published an important work in Germany in 1928—*The Rocket into Interplanetary Space*—that envisioned unmanned instrument carriers, manned spaceships, and manned space stations.

German rocket studies eventually won government support. On the eve of World War II, the Nazi Reich was spending one-third of its entire aerodynamic research budget at the Peenemunde rocket base. Twelve thousand workers were employed there and about 1,000 qualified researchers elsewhere in the country. Their efforts brought forth the V-1 and V-2 rockets that were sent against England in 1944.[12] The German rockets marked a tremendous advance in technology and clearly established the possibility of future space flight.

After the war American scientists, and German scientists who had come to this country, initiated high altitude studies with the aid of V-2 rockets. The Viking II, fired in May 1954, reached an altitude of 158 miles. During the International Geophysical Year in 1957, the Naval Research

[12] The V-2 was able to fly nearly 200 miles with internal gyroscopic guidance that held it accurately on course. It was 46 feet long, weighed 14 tons, and flew at 4,000 miles an hour.

Laboratory developed the ill-fated Vanguard, consisting of three rocket stages with a total weight of a little over 10 tons. Not until after the launching of Sputnik I, in October 1957, did the Department of Defense authorize use for civilian experiments of the large military missiles which it had developed to carry warheads.

The first American satellite launching—of Explorer I on Jan. 31, 1958—carried a 30.8-pound load aloft on top of a U.S. Army Jupiter C missile, a direct descendant of the V-2. The Explorer was credited with discovery of a global radiation belt, identified by and named for James A. Van Allen. No more important space discovery has been made to date. Vanguard I, propelled by Navy test vehicles, was orbited on March 5, 1958. Since then, the United States has sent aloft 52 more earth satellites, in addition to two deep space probes and two solar satellites, mostly by means of launch vehicles designed for military purposes.[13]

The satellites have gathered extensive information on radiation levels, cosmic ray activity, frequency of low-energy particles and other factors expected to affect long-distance manned flights. Pioneer V, launched into solar orbit on March 11, 1960, for example, was tracked into space a distance of 22.5 million miles, the greatest distance any man-made object has been tracked. According to Herbert Friedman, superintendent of the Astrophysics and Atmosphere Division of the Naval Research Laboratory, an Aerobee-Hi rocket shot on Aug. 29 virtually doubled the accumulated data on solar radiation, but much more exploration of radiation in outer space is considered necessary in preparation for a manned flight to the moon.

Success of the First Project Mercury Shots

The effort by the United States to place a manned space capsule in orbital flight around the earth—Project Mercury—got under way in October 1958. Investigation of man's performance capabilities and ability to survive in a true space environment, as well as means of safe re-entry into the earth's atmosphere, were prime initial objectives. A significant step in the program was taken last Jan. 31 when a Mercury-Redstone missile raised a chimpanzee to an alti-

[13] One-third of all launches were successful in 1959, two-thirds in 1960. The latest American earth satellite to be launched, the Midas IV on Oct. 21, is a 3,500-pound vehicle which carries an infra-red eye and can transmit pictures back to earth as it passes over strategic areas of the world.

tude of 156 miles while traveling downrange about 420 miles.

Then, on May 5, Commander Alan B. Shepard, Jr., of the U.S. Navy became America's first astronaut. Shepard spent five minutes at zero gravity as his rocket capsule, fired from Cape Canaveral, reached an apogee of 117 miles. He reported, after landing 300 miles downrange, that his manual controls had worked effectively and that the launch and re-entry accelerations had been identical with those simulated many times during training. Riding through the fringes of outer space, Virgil I. Grissom, America's second astronaut, was carried the same distance downrange at about 5,000 miles an hour when his Mercury capsule was launched from Cape Canaveral on July 21.

An unmanned Mercury capsule was fired into orbit on Sept. 13 and brought down safely east of Bermuda after a 109-minute circuit of the earth. The capsule, occupied by a robot, was the first vehicle orbited by the United States that could have carried a human being. The highly successful 17,519 mile-an-hour flight buoyed hopes that an astronaut might orbit the earth this year, but NASA officials said there would have to be at least one more test flight before a man was sent aloft. On this test a chimpanzee will be sent three times around the earth at an altitude of about 100 miles and at a speed of 17,400 miles an hour.

Another unmanned three-times-around shot probably will be made to test the ability of the Atlas launch vehicle to release the spacecraft at the precise speed, altitude and flight-path angle needed for orbital flight and check the operation of the spacecraft and its instruments. Despite the high degree of technical skill displayed, the House Committee on Science and Astronautics observed in a report on June 29 that "Project Mercury represents the Wright Brothers phase of space flight" and was "sure to appear as crude and daring to future generations as the clumsy wood and cloth 'kits' of aviation's bygone era."

Plans for Manned Flights; Preparatory Probes

Project Mercury is only the first phase of a space-flight program designed to lead to landing of men on the moon. Project Mercury, once successful, will give way to Project Apollo. The first Apollo spaceship is to be hurled into earth orbit sometime after 1963 by a Saturn launch vehicle

with a total thrust of 1.5 million pounds. This compares to the thrust of only 78,000 pounds that dispatched Shepard and Grissom on their Redstone-Mercury flights.

The Apollo lunar craft will be large enough to provide living and working quarters for a three-man team who will carry out a variety of scientific experiments while training for sustained space flight.[14] The flights around the earth will be followed by voyages deeper into space, including a trip around the moon and return to earth. Finally will come the actual moon landing and the return flight.

The whole Apollo moonship is expected to weigh 75 tons, but only parts weighing 17 tons will land on the moon, and only a final stage weighing about 8,000 or 9,000 pounds will return to earth. Among the requirements for the Apollo spacecraft are: (1) a life-support system to provide a suitable environment for a period of more than two weeks; (2) radiation shielding to give the occupants protection during passage to and from the moon as well as on the lunar surface; (3) a navigation system which will afford automatic guidance; (4) an altitude stabilization system which will permit orientation of the spacecraft for thrust control; and (5) communications equipment for all phases of the flight.[15]

Manned moon landings will be preceded by instrument flights to the moon and extensive lunar exploration. Ranger I, a 675-pound tower of instruments, rose from its pad at Cape Canaveral on Aug. 23 and was to have been the first of the American vehicles to explore the moon. However, it failed to go into the proper orbit. Ranger II, whose recently scheduled launching had to be postponed, is to fly past rather than hit the moon, in an effort to obtain scientific information on the moon's environment. Television cameras will send back images of the moon to earth.

Future Rangers will embody key engineering experiments for lunar and interplanetary space vehicle design. Powered by a new, two-stage Atlas-Agena rocket, they will carry particle detectors, magnetic field analyzers, solar X-ray detectors, solar corpuscular radiation analyzers, cosmic ray ionization recorders, and cosmic dust detectors. Instrumentation packages will be similar so that any single suc-

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[14] George M. Low, "NASA Space Flight Programs—Manned Space Flight," speech at Tulsa, Okla., May 26, 1961.

[15] Robert Seamans, Jr., speech at Los Angeles, Aug. 29, 1961.

cessful flight can be counted upon to yield useful data.[16]

Rangers III, IV, and V will make the 66-hour, 288,000-mile flight to the moon in 1962 and will land on the lunar surface. A 300-pound package is to be detached from the Ranger vehicle about 20 miles above the moon's surface and slowed somewhat by a "retro" or backfiring rocket. The payload will be encased in balsa wood to absorb the shock of a 300-mile-an-hour landing. At its center will be a 50-pound seismometer to take rudimentary soundings after landing. By analyzing the shock waves, scientists hope to gain an idea of the structure and composition of the moon.[17]

The next series of vehicles, scheduled to follow in 1964, will be Surveyors. The Surveyors also will land on the moon but will be much more heavily laden with instruments and retro-rockets. They will be able to slow down to about six miles an hour before lunar impact. The "soft-landing" Surveyors will take panoramic shots of the moon, will drill into the lunar crust to extract samples, and will telemeter all data back to earth for chemical analysis. These first two families of probes may in turn give way in 1966-68 to still another lunar spacecraft, the Prospector. About the time the first Apollo team lands, unmanned Prospector probes will roam the lunar surface, sending back color television images and picking up moon samples to return to earth.

Achievements of the Soviet Union's Spaceman

Ever since the race into space began on Oct. 4, 1957, with Russia's orbiting of a 183-pound satellite, the Soviet Union has kept in the lead. During the past four years the Russians have put 13 earth satellites into orbit, shot two satellites into orbit around the sun, and landed a capsule on the moon. Although the United States has launched four times as many satellites, most of them more elaborately instrumented, the Soviet satellites have been generally heavier. Possession of boosters with a thrust of more than 600,000 pounds enabled the Russians to score a series of significant "firsts." After putting up the first sputnik, they were the first to send a satellite (Lunik I) into solar orbit, Jan. 2, 1959. A 58-pound Soviet vehicle (Lunik II)

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[16] James D. Burke, "Ranger Spacecraft," *Astronautics*, September 1961, p. 23.

[17] Jerry E. Bishop, "Space Exploration," *Wall Street Journal*, June 22, 1961, p. 13.

complete with hammer and sickle hit the moon on Sept. 12, 1959. Lunik III photographed the far side of the moon on Oct. 4, 1959, and still another Soviet device blazed a trail to Venus last February.

Russian life-in-space experiments began Nov. 3, 1957, when a 1,120-pound sputnik carried a dog named Laika into outer space. The first prolonged flight came on Aug. 19, 1960, when two dogs, Belka and Strelka, were returned to earth on command after circling the globe 18 times. A space ship carrying a variety of animal life burned up last Dec. 1 when it failed to go into proper orbit, but two subsequent flights with animals aboard were successful.

Russia's greatest space triumph was achieved on Apr. 12 when Yuri A. Gagarin became the first man to orbit the earth. On a flight lasting 108 minutes, Gagarin's spaceship reached a top speed of more than 17,400 miles an hour. The spacecraft, Vostok I, weighed over five tons and was hurled upwards by a rocket with about 800,000 pounds of thrust. Gagarin reported that he suffered no ill effects during the 89 minutes he was in a state of weightlessness; his working ability was not impaired.

The second Soviet cosmonaut, Gherman S. Titov, whose spaceship circled the earth 17 times in 25 hours and 18 minutes on Aug. 6-7, did report some nausea. Titov's flight, the most spectacular of man's attempts to explore outer space to date, was made in a spaceship of about 10,400 pounds. The Vostok II traveled in an orbit that took it about 160 miles from the earth at its farthest point and about 111 miles at its closest. While Titov was flying over the Soviet Union, the television system in his cabin relayed images back to the ground.

Soviet Premier Nikita S. Khrushchev said that Titov's flight had "fulfilled mankind's dream." But A. A. Mikhailov, chairman of the Soviet Academy of Sciences Astronomical Council, cautioned Oct. 4, 1961, that the safe landing of man upon the lunar surface was still "years away." Mikhailov said that "Only after thorough investigation and when there is a complete guarantee of a safe return to earth, only then will a man be landed on the moon." It is anticipated that the Russians will launch a spacecraft larger than the Vostok II within a few months and that it may carry two, even three, men in prolonged flight around the earth.

Technical Difficulties in Space Travel

MORE POWERFUL launch vehicles and propulsion systems constitute by far the greatest need of this country in space exploration.[18] The chemical rocket engine is the only present power system capable of propelling vehicles into space beyond the heaviest pull of the earth's gravity. However, the huge chemically propelled rockets necessary to send a man from earth directly to the moon and back have serious drawbacks. They are unwieldy, costly, and unpredictable.

In view of the U.S. space lag, some government officials have been considering plans for putting large manned space stations into orbit around the earth. These stations would carry 10 to 12 astronauts and would be used as departure points for the moon and the planets. Such stations could be used also as service stations for communications satellites.

It is not yet clear whether it will be more practical to launch a manned lunar vehicle from a platform in outer space or from the earth. Similarly, it might be far easier to have a team take off from a space station orbiting the moon than to have a vehicle make a direct voyage from earth to a designated spot on the moon's surface. A principal difficulty lies in bringing about meetings high above the earth of various spaceships and satellites. James R. Dempsey, president of General Dynamics Astronautics, asserts that if the United States cannot find a way to effect the rendezvous of a spaceship with a satellite 300 miles up, "You can't rendezvous with the moon 240,000 miles away."[19] In any case, the rendezvous technique will have to be used for exploration of far distant space, and so it is asserted that the development work might as well begin now.

Controversy Over Liquid vs. Solid Rocket Fuel

The advantages of liquid over solid fuel, or vice versa, as a propellant for the first stage of manned rocket flights are still being debated. On the decision may rest this

[18] A space exploration vehicle, whether manned or unmanned, consists of a propulsion system, a guidance and control system, a payload, and a frame uniting these components.

[19] Quoted by William Hines, "Operation Moon," *Washington Star*, Sept. 16, 1961, p. 1.

country's chances of beating Russia to the moon. The United States has been planning to use liquid fuels, such as liquid hydrogen, oxygen and kerosene, in all stages of the giant space vehicles to be launched during the next few years. But the builders of solid-fuel rockets, encouraged by the success of such missiles as the submarine-fired Polaris, now contend that the first or booster stage of the rockets should be propelled by solid fuel.

The partisans of solid-fuel boosters maintain that they are much more reliable, and can give much higher speeds, than the liquid-fuel boosters now being developed for NASA. They assert that concentration on the solid-fuel boosters might result in savings of as much as $1 billion over the next decade and put the United States ahead of Russia in rocket propulsion by 1965.[20] President Kennedy told Congress last May 25 that his administration proposed to build both liquid and solid fuel boosters until "certain which is superior." Expenditures on solid-fuel rockets have been sharply stepped up during recent months.

Solid fuels have a rubbery base which makes for easy handling. They are composed about 20 to 30 per cent of burning agents (aluminum flakes or other metal additives such as magnesium) and about 70 per cent of an oxidizer (such as ammonium perchlorate) which supplies the oxygen needed for combustion. A synthetic resin binder holds the mass together. These chemicals are mixed, poured into slabs, and baked to give them rigidity. The chief advantage of using a solid fuel is its simplicity. The engines are essentially long tubes with a hole down the middle. Exploding a charge at the top sends a blast of flame down the hole and ignites the fuel. Add a guidance system and the rocket is ready for firing. No other moving parts are needed.

The Air Force's Minuteman intercontinental missile is propelled by solid fuel. H. L. Thackwell, senior vice president of the Grand Central Rocket Co., thinks the most practical way to achieve the huge thrusts needed for future space shots would be to build large solid-fuel segments, fasten them together at the launch site, and enclose them in a heat-treated steel shell about one-half inch thick. Such boosters would be of great size. The first stage would weigh more than six million pounds and develop over 12

[20] Robert Keatley, "Rocket Tug of War," *Wall Street Journal*, July 7, 1961, p. 1.

million pounds of thrust. The four stages would tower about 380 feet over the launching pad.

American Progress in Use of Liquid Propellants

In liquid propellant rockets, liquid oxygen and some jet fuel or liquid hydrogen are pumped into a combustion chamber from separate tanks. The gases formed by combustion push the rocket up, but the engines, such as NASA's Rocketdyne F-1, require complex and costly pumps which must move three tons of fuel a second. The pumps contain a maze of electrical conduits, and one short-circuit can frustrate a launching and perhaps delay a flight for weeks. Moreover, the handling of sub-zero liquid oxygen and liquid hydrogen holds many risks because of the corrosive effects of these elements on the containers.

It is thought that the Russians have clustered three or four 250,000-pound-thrust, liquid-fuel missile boosters for the first stage of their recent launchings. Proponents of liquid fuels assert that they produce more thrust per pound of rocket weight, and that ready-mixed fuels have now been developed which can be held in one tank until the rocket is ready for launching. Ready-mixed liquid fuel would simplify the rocket structure and cut down risk of the mishaps which have plagued America's space program in the past. The liquid-fuel companies believe that in the near future it will be possible to recover boosters for re-use. As liquid fuel is relatively cheap, this would drastically cut launching costs.

The H-1 rocket engine, now set for production, has 188,000 pounds of thrust using liquid oxygen and kerosene. Eight H-1 rockets were clustered in the first stage of the recently tested Saturn vehicle to produce 1.5 million pounds of thrust, four times that of the Atlas, which has been the most powerful single American rocket. Modified versions of the Atlas are to be used to generate about 360,000 pounds of thrust for the Centaur, which is scheduled to begin test flights soon. The Centaur will be used in the Ranger and the Surveyor series during the next three years.

Test firing of the F-1 engine began last July. Designed to develop 1.5 million pounds of thrust in a single-chamber engine, the F-1 is being considered for the first stage of Project Nova. Using a high-energy liquid hydrogen-liquid oxygen propellant, this engine should be able to meet all

of the country's thrust needs for a long time. Each F-1 engine will weigh 15,000 pounds without fuel and cost more than $10 million. Its "specific impulse" will be above 400.[21]

PROPULSION SYSTEMS FOR INTERPLANETARY TRAVEL

The chemical rocket engine, using either liquid or solid fuels, is not considered practical for protracted space voyages. Although the thrust created by the chemical reactions is high, it is extremely difficult to stop a rocket engine propelled by solid fuel without destroying it. Once a rocket engine propelled by liquid fuel is halted, injection manifolds must be cleaned before restarting. Moreover, the chemical nature of these rocket engines creates design problems and involves many operational hazards.

Nuclear propulsion for spaceships has been under consideration for some time. On June 7 the Atomic Energy Commission and NASA, partners in Project Rover (the nuclear rocket project), announced that the first phase in development of NERVA (Nuclear Engine for Rocket Vehicle Application) had been tested. NERVA will not be propelled by controlling an atomic reaction but by putting an atomic reactor's heat to work. Liquid hydrogen, for example, will be injected into the core of a fission pile placed near the rocket's exhaust. Heat of about 3,600 degrees Fahrenheit from the nuclear reactor will expand the hydrogen and cause it to escape through a nozzle giving exceedingly high exhaust speeds. Such propulsion offers a tremendous advantage over chemically powered rockets in that no oxidizers need be stored on the spaceship. No combustion takes place; therefore, no oxygen is required. It has been estimated that a nuclear-powered rocket may be flown by 1966-67 and that the cost of the engine will exceed $500 million.

Use of nuclear fusion directly as a means of propulsion is not likely in the foreseeable future. No prolonged fusion reaction has been achieved to date, and the shielding and machinery necessary to control fusion would probably be prohibitively heavy. A type of nuclear propulsion that would utilize the energy from radioactive isotope decay is thought to be more practical. Decay of radioactive isotopes

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[21] Rocket fuels are rated by "specific impulse," or the number of pounds of thrust generated for each pound of fuel consumed per second. Solid fuels rate about 240, while liquid mixtures of kerosene and oxygen have a rating of about 300.

gives off energy in the form of radiation which can easily be converted to heat. With the large amount of shielding needed to protect occupants for the spaceship, however, such rockets would be suitable only for low thrust-to-weight ratios.

The ion-propulsion rocket, whose thrust-to-weight ratio is about 1,000 times below that of present liquid-fuel rockets, would be ideal for achieving high speeds over a prolonged period of time. An ion rocket being developed by the Hughes Aircraft Co. will consist of a tiny atomic reactor which generates heat to drive a turbine. The turbine is connected to a generator which sends a high voltage across parallel grids and accelerates ionized cessium atoms to fantastic speeds. Such a rocket, while potentially fast, could operate only in the vacuums that exist between planets; it could not overcome a strong gravitational field. Total thrust of the rocket would be no more than 10 pounds. A complete ion propulsion system may be tested by 1965 according to Hughes Co. officials.[22]

Recent testing of a plasma-pinch engine, developed by Republic Aviation, has been successful. In this engine nitrogen is fed into a one-inch-wide space between two electrodes about an eighth of an inch in diameter. By throwing a switch, a 3,000-volt charge is applied across the electrodes, ionizing the nitrogen atoms. The resulting mixture of electrons and ions, called a plasma, is forced toward a nozzle and ejected at a rate of about 100,000 miles an hour by the pressure of a magnetic field set up by the electric current flowing through the plasma.[23] The Republic engine is powered by a battery designed to be recharged in space by solar cells. The whole engine weighs only 150 pounds and is about 20 inches in diameter. A flyable model will be ready early next year.

Biomedical Hazards Attending Travel Into Space

Many of the biomedical problems facing future space travelers are still unknown and may cause long delays in carrying out space exploration timetables. Intense radiation during solar disturbances, for example, may be one of the chief obstacles to prolonged manned space flight. Large storms on the surface of the sun spew out vast

[22] William L. Lawrence, "Space Travel Fuel," *New York Times*, Oct. 1, 1961, p. E.-7.

[23] R. J. Bondie, *Aeronautics Bulletin* (St. Louis University), March 1960, p. 2.

clouds of protons in the form of hydrogen-atom nuclei charged with millions of volts of energy. Balloon flights carrying mice to altitudes of more than 130,000 feet were staged by the Air Force in June 1960 to learn the effects of these protons on animal tissue. Mold spores, viruses, and various membranes also were sent aloft to determine the extent of damage caused by cosmic rays and ionization. Discoverer XVII, launched last November during one of the largest solar flares on record, revealed that the radiation dosage within the cabin was well within the limits which medical men consider acceptable.

Discovery in 1958 that the earth was surrounded by two distinct and separate belts of intense radiation, with a belt of low-level radiation between—the Van Allen radiation belts—has given concern to space biologists. No human being or animal has yet passed through these belts. They stretch from a point about 600 miles from the earth to a point as much as 100,000 miles distant, with peak intensities at 2,500 and 10,000 miles. The intensity of radiation recorded, even in the buffer zone, has registered minimum rates per hour equaling the maximum weekly dosage regarded as safe by the Atomic Energy Commission.[24]

However, the particles trapped in the Van Allen radiation belts may not be serious hazards for astronauts carried through them at a high rate of speed. A certain amount of internal lead shielding will probably protect against most radiation, but there is no possibility of shielding a spaceship completely against cosmic rays; lead about three feet thick would be required to afford the screening effect of the earth's atmosphere. Thin shielding, on the other hand, might actually increase the amount of radiation by providing a source of secondary rays, many of which are produced in any case by the walls of the spaceship.

In a paper presented to the International Astronautical Federation in Washington on Oct. 4, two Soviet academicians discussed the unpleasant sensations associated with the ear chamber that were experienced by Titov on his 435,000-mile multi-orbit flight. The cosmonaut's dizziness raised the question of whether the human system could endure long periods without the accustomed effects of gravity. The Russian scientists reported that during

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[24] Arthur C. Clarke, *Interplanetary Flight* (1960), p. 105.

weightlessness there were indications of a "definite instability of central nervous system reactions," including a "relative instability" in heartbeat and "non-uniformity in breathing."

For short space flights weightlessness seems to be no problem, but on longer flights the reactions of the spacemen may well be impaired. The Russians say that the ill effects of weightlessness could be corrected by creating artificial gravity in the spaceship, but creation of artificial gravity, if feasible, would necessitate a substantial increase in the weight of spaceships. Prolonged weightlessness may affect ability to eat, drink, and digest food, as well as ability to control the muscles for rapid and exact performance of complex duties. It has been speculated that severe temporary muscular weakness might result from prolonged periods of weightlessness.

Psychological hazards also are of concern to scientists. Total isolation over many hours can produce hallucinations and other mental disturbances. Ross Adey, a physician at the Brain Research Institute of the University of California at Los Angeles, said on Oct. 19 that the stresses of blasting into space might cause an astronaut to react temporarily like a punch-drunk boxer. Ability to judge the passage of time and to preserve a sense of direction, such as up and down, also may pose serious problems because their meaning will be only relative for the astronaut. Some of the physical and mental effects of a trip to the moon can be predicted and prepared for on earth, but knowledge of the total effect of all the varying factors will be gained only from actual experience in prolonged space flight.